IS 10020-4 (1981): Recommendations for design and construction of port and harbour components, Part 4: Slipways [CED 47: Ports and Harbours]

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IS : 10020 (Part IV)- 1981

Indian Standard

RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF PORT AND HARBOUR COMPONENTS

PART IV SLIPWAYS

UDC 627·33 : 624·04 : 629·128·2

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 6

September 1982

Indian Standard

RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF PORT AND HARBOUR COMPONENTS

PART IV SLIPWAYS

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Indian Standard

RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF PORT AND HARBOUR COMPONENTS

PART IV SLIPWAYS

0. FOREWORD

0.1 This Indian Standard (Part IV) was adopted by the Indian Standards Institution on 30 November 1981, after the draft finalized by the Ports and Harbours Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 This standard is being issued in various parts to cover various components of ports and harbours. This part (Part IV) covers the recommendations for design and construction of slipways.

0.3 Slipways are one of the facilities provided in ports for reconstruction and repairs of vessels in dry condition. Slipways are inclined ways made of timber or stone or steel or concrete running up from a sufficient depth of water to the requisite height above high water level, upon which a series of rails or steel joists are fixed. On these rails or steel joists cradles run to support the vessel and are hauled up or lowered down by means of hauling gear.

0.3.1 This standard (Part IV) has been formulated to cover the recommendations for planning, design and construction of slipways.

0.4 In the formulation of this standard, due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard (Part IV) covers the planning, design and construction of slipways for repairs or overhaul of vessels.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given IS : 7314-1974* shall apply.

3. PLANNING

3.1 Selection of Location — The conditions given in **3.1.1** to **3.1.11** should be satisfied for a good location of a slipway.

3.1.1 The site should be reasonably sheltered from high winds, waves and strong currents. The wave should not be more than 0·3 to 0·6 m in height at the time of slipping.

3.1.2 The site should not be subjected to either excessive siltation or erosion and should have a reasonably stable bank.

3.1.3 The bearing capacity of the soil in the area shall be sufficiently high to enable a foundation that will preclude undue settlement.

3.1.4 There should be adequate distance from the high waterline to the approach channel so as to provide safe fair way for vessels approaching or leaving the slipway.

3.1.5 Adequate depths of water should be available at the down haul end of the slipway to accommodate the proposed maximum size of vessel and its cradle, over the slipway. It should have adequate depth of water for the proposed maximum size of vessel to be slipped.

3.1.6 The site should have easy approach and sufficient space for manoeuvering of the vessel.

3.1.7 There should be sufficient adjoining land for provision of transfer track, repair berths, winch houses, workshops and offices and for future expansion.

3.1.8 Slipways should be so sited as to avoid interference with future development of other port facilities like wharfage, rail and road approaches, etc.

3.1.9 There should be good accessibility for transportation.

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*Glossary of terms relating to port and harbour engineering.

3.1.10 Adequate electric power, water supply, compressed air and cranage facilities should be available.

3.1.11 Adequate length of wharfage in the vicinity is desirable for carrying out afloat repairs.

3.1.12 The slipway should be constructed near to a well-developed modern port with industrial capacity for the repair and manufacture of ships.

3.2 Site Investigations

3.2.1 For the purpose of selection of a suitable site for the slipway, comprehensive survey of physical topography of the area, hydrographic survey of the approaches to the site of the slipway and the adjoining bank of the site to a considerable distance on either side of the proposed site should be conducted.

3.2.2 The velocity and duration of predominant and prevailing winds at the proposed site for at least the last ten years should be ascertained.

3.2.3 All topographic, oceanographic and soil investigation data as enumerated in IS : 4651 (Part I)-1974* shall be collected for the site.

3.3 Orientation of Slipway

3.3.1 Slipway should preferably be oriented such that the vessels, while being manoeuvred or slipped on to or off the cradle, should not be broadside to the predominant strong winds or currents and should make as acute an angle as possible to the strong winds and currents.

3.4 Docking of Vessels

3.4.1 For rapid slipping anywhere, and for slipping at sites where tidal conditions are particularly unfavourable, it is essential to hold the vessels securely in position while centring over the cradle. Where this could be done from adjoining wharves or walls, no other facilities are required; but usually it is necessary to construct fixed mooring dolphins, or a small lead-in jetty fitted with at least two mooring bollards and a fairlead for handling the lines from the vessels.

3.4.2 To indicate the centre of the submerged cradle, when the vessel is being centred over it, an indicating staff may be fixed at the centre of the upper end of the cradle to project vertically out of the water surface. More efficient and satisfactory arrangement is to build side framing on to the cradle on three sides to define the outline of cradle when under water and to guide the vessel into position.

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*Code of practice for planning and design of ports and harbour: Part I Site investigation (*first revision*).

3.5 Types of Slipways

3.5.1 Slipways are either of the end-on type (*see* Fig. 1) or broad-side pattern (*see* Fig. 2) according to whether, the vessel is hauled clear of the water in the direction of its length or normal to this direction.

3.5.2 An end-on slipway requires considerably less water-front space than the broad-side slipway which may form an important consideration. An end-on pattern would require only 1/3 water front of broad-side pattern and also operation is safe and less complicated due to a lesser area of the vessel offering resistance in the direction of the haul.

3.5.3 In order to enable to effect repairs for several vessels simultaneously, the slipway may be provided with transfer tracks and transfer cradle and repair berths. The transfer track will run perpendicular to the slipway track, and the repair tracks, perpendicular to the transfer track (or parallel to the slipway) as shown in Fig. 3.

3.5.4 When the vessels are to be transferred to transfer cradle and repair berths, it is desirable and convenient if the vessels are brought to horizontal position from the inclined position. For bringing the vessel to the horizontal position, one of the following three systems can be adopted:

a) A vertical curve in the slipway track, or

b) A tilting bridge at the top end of the slip, or

c) A subsidiary sloping cradle under the main cradle.

3.5.4.1 The vertical curve has limitations and is suitable only for small vessels up to 150 tonnes for end-on pattern, because the cradle has to be supported only at two ends (like a railway bogie) and the diameter of wheels increases considerably with higher loads.

3.5.4.2 Tilting bridge can be made use for vessels up to 300 tonnes. For heavier vessels it would require very heavy foundations and powerful synchronised jacks because the bridge tilts on a single point support (*see* Fig. 4).

3.5.4.3 Sloping cradles would have no limitations as the main cradle is kept on a sloping cradle which compensates for the slipway with a triangular structure as shown in Fig. 5. However, this would require long slipways and greater depths of water at the end of the slipway to accommodate the height of the sloping cradle and also extra power for hauling the weight of the sloping cradle.

3.5.5 For broad side pattern, vertical curves would be very advantageous because of the large number of wheels available to take the load.

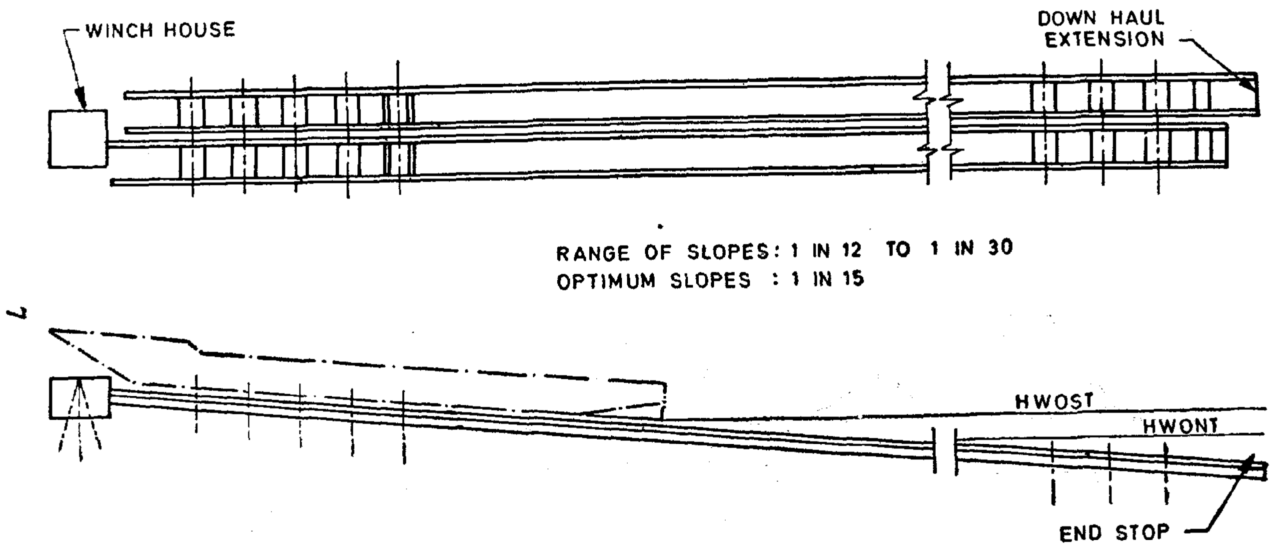

FIG. 1 END-ON SLIPWAY

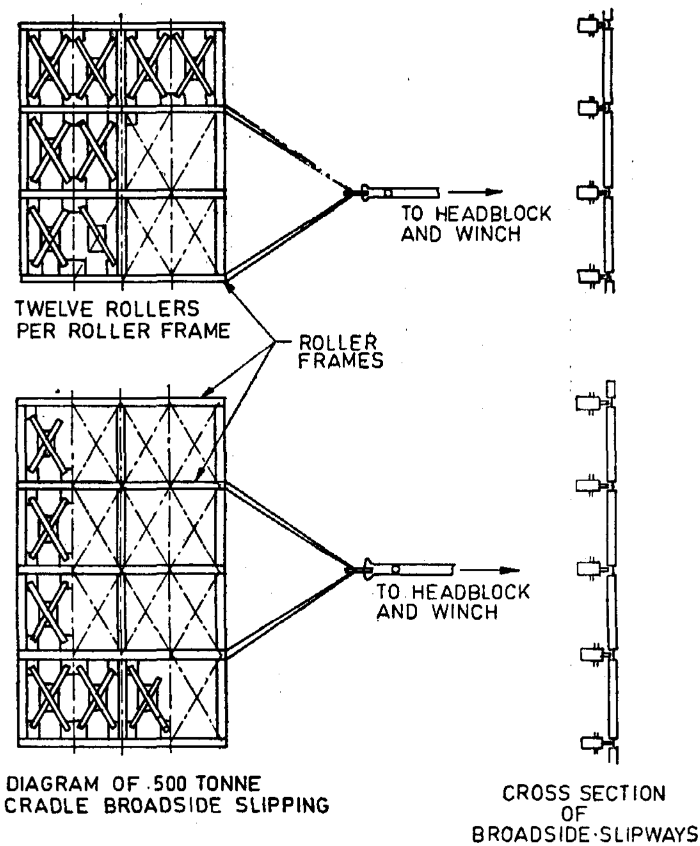

FIG. 2 TYPICAL CRADLE

3.5.6 The transfer cradle will have rails on top at the same level as that of the top end of slipway or tilting bridge or the sloping cradle to take the main cradle on to the transfer cradle. The rail top of the repair track will be at the same level as that of the transfer cradle rail. The main cradle is hauled on to the transfer cradle by the main winch. The transfer cradle is hauled by a side winch to the front of the required repair track and the main cradle is again hauled on the repair track from the transfer cradle with the help of side winch and pulley system.

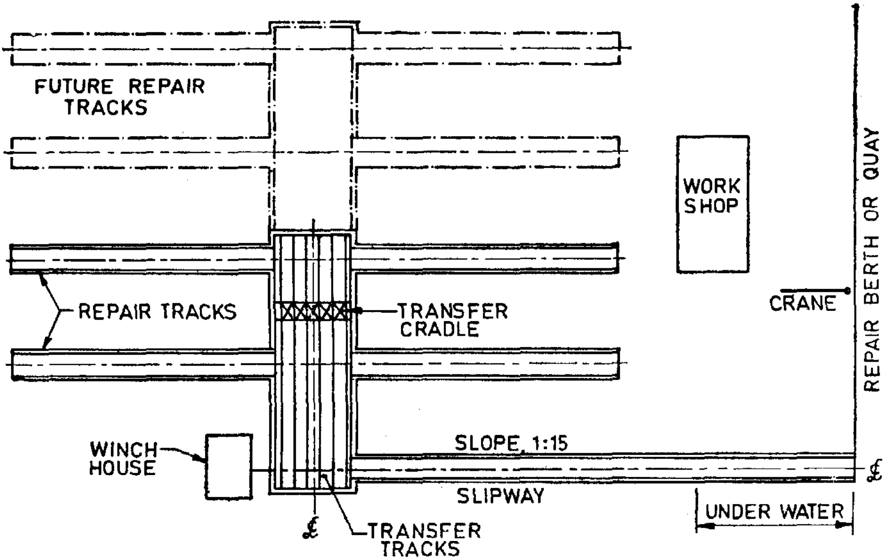

FIG. 3 SLIPWAY LAYOUT

3.5.7 In order to enable more than one vessel to be dealt with on an end-on slipway, it may be provided with side slipping arrangement (Fig. 6). In such cases, vessels are slipped out of water in the end-on position up the slipway and at the top, traversed sideways on either side of the main cradle. This may be done by mounting side traversing cradles on cross rails on the main cradle. The rails should be interlocked with the fixed cross rails of the side berths at the top of the slipway and the traversing cradles be hauled over by winches. For very small vessels, a turntable (Fig. 7) arrangement with a number of layout berths could also be provided.

3.6 Cradle and Cradle Supports

3.6.1 The cradle is a framework of timber and/or steel consisting of two or more longitudinal beams and cross beams to support the keel and bilge blocks. In case of three or more central longitudinal beams the central unit will have to be designed for full load of the vessel while the side longitudinal beams will have to be designed at least for 1/3 of the vessel load plus likely wind loads on the broad side of the vessel to withstand loads due to any tilt of the vessel to one side. The top of the keel blocks may be sloped inwards to the centre so that the vessel slides to the centre of the cradle by its own weight as it is hauled out of water. The bilge blocks have to be made sliding or adjustable to fit the different shapes

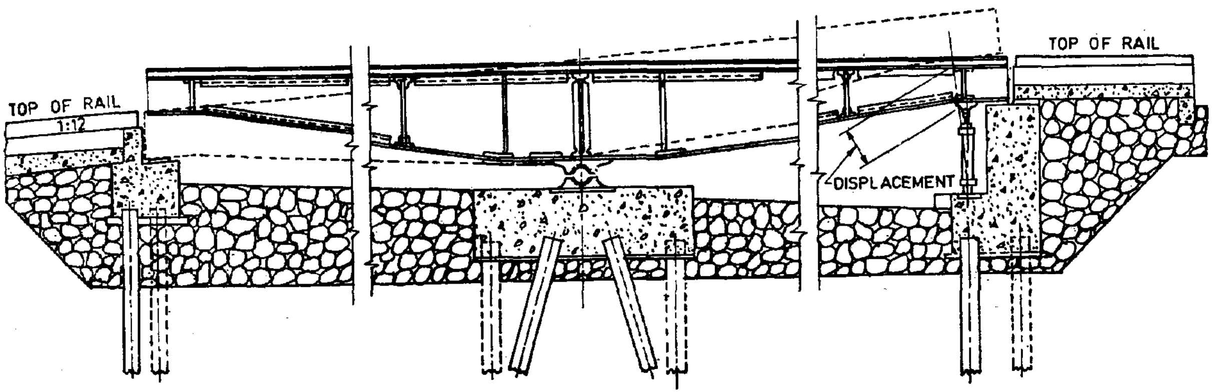

FIG. 4 TILTING BRIDGE WITH TWO DOUBLE ACTING HYDRAULIC JACKS

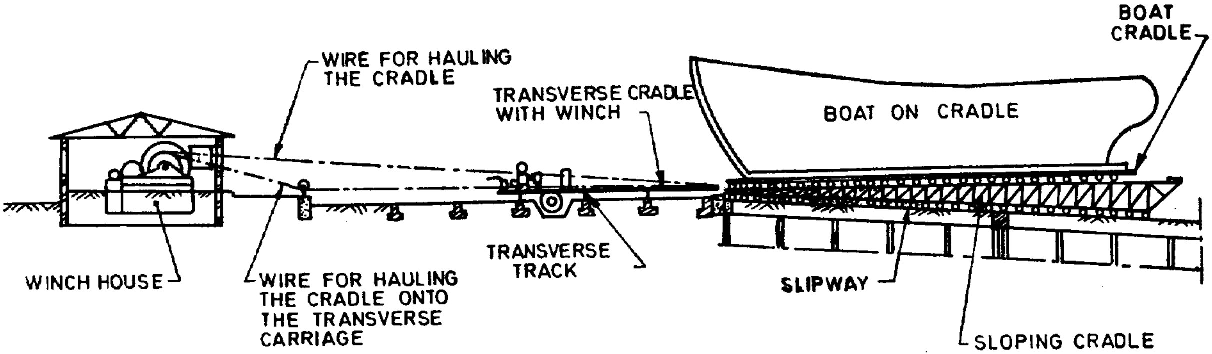

FIG. 5 SLOPING CRADLE

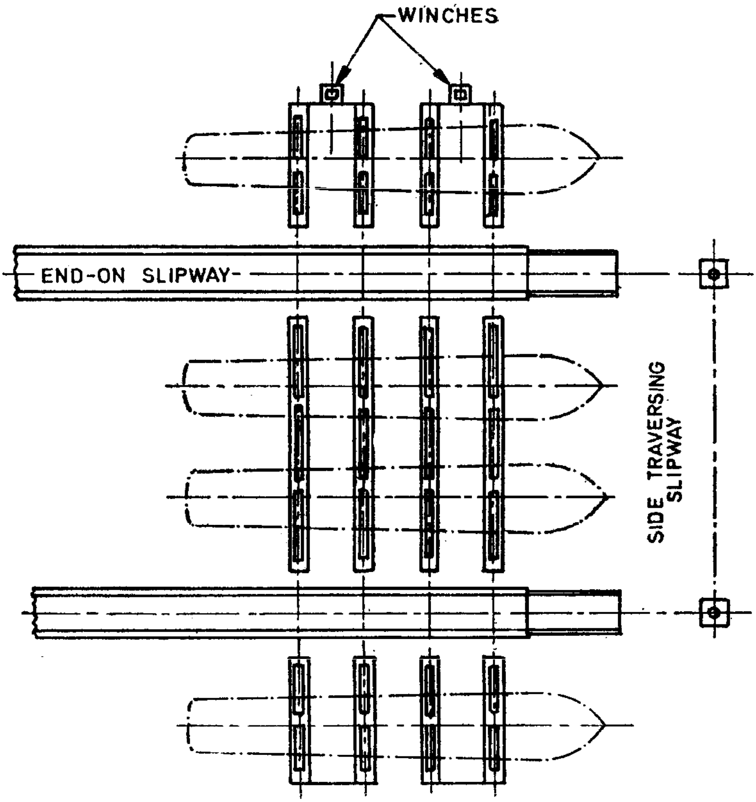

FIG. 6 LAYOUT OF SIDE-TRAVERSING SLIP

of vessels. The whole structure is to be mounted on wheel trains or numerous cast iron rollers of required diameter working in a steel carriage. Cradle may be single unit or in several units so that the required length can be obtained by joining the units. The cradle need not be equal to the length between perpendiculars (LBP) of the largest vessel proposed to be hauled but can be shorter by 1/4 the LBP so that about 1/8 of the vessel may overhang on either side as the loads at either ends would be very small due to the shape of the vessel. A plough for the removal of accumulation of silt over the rails may be a desirable attachment. Pawl racks are attached to the beam carrying the rails and the pawl lever to the central longitudinal of the cradle at intervals of about 6 metres to prevent back-slip of the cradle in case of winch or rope failure.

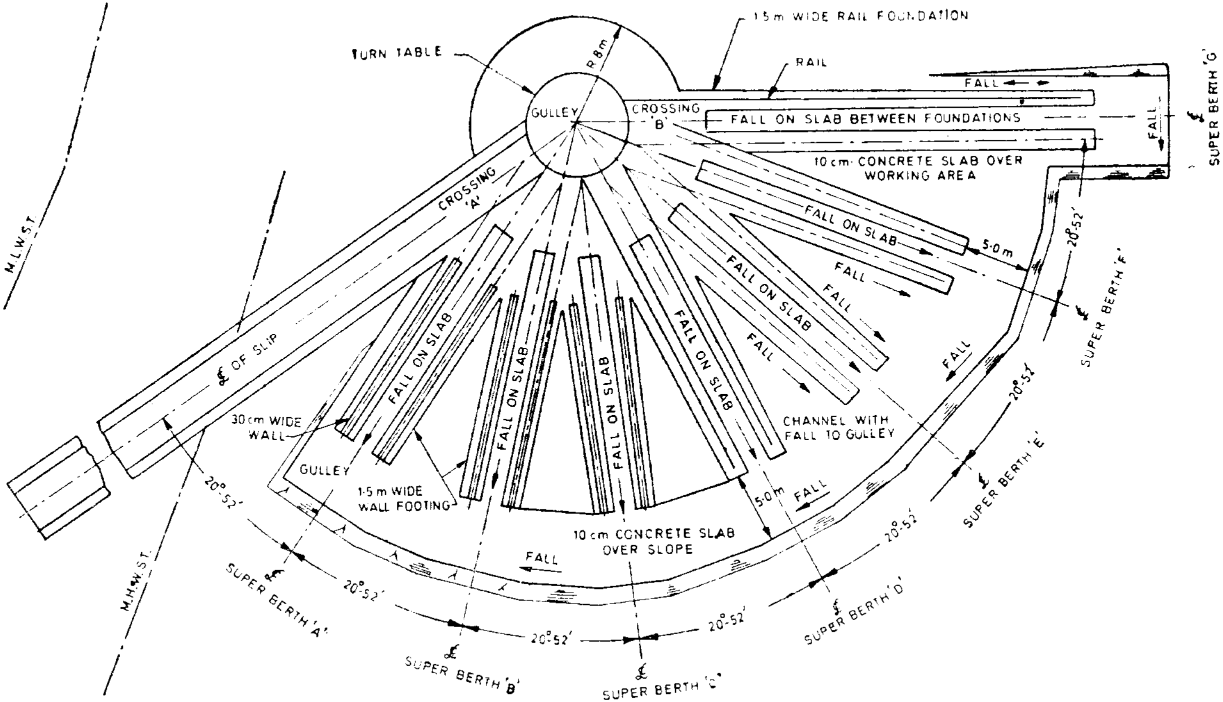

FIG. 7 END-ON SLIPWAY WITH TURNTABLE ARRANGEMENT

3.6.2 The cradles are of three types (a) rigid, (b) semi-rigid, (c) telescopic or collapsible. The design of the cradle depends to some extent whether live roller system or the wheel and bearing system is employed.

3.6.3 *Rigid Cradle*

3.6.3.1 Considered from the operational angle the rigid cradle with continuous wheel trains on each rail is the best. But the wheel trains interfere with clear access to the bottom of vessels in their vicinity and the slip has to extend into the water to the full length of the cradle to accommodate the whole of the cradle.

3.6.4 *Semi-rigid Cradle*

3.6.4.1 The semi-rigid cradle is a compromise between the rigid and the collapsible. With this type, it is possible to deal with not only vessels of the maximum size for which the slipway has been designed but also with two or three small vessels simultaneously. The cradle in this type is divided into three or more parts connected together by chains. By this arrangement the length of the slipway underwater, where the construction is more expensive, is reduced to the extent of the sum of the lengths of the connecting chains. Also a portion of the wheel trains may be moved out of the way to give access to the bottom of the vessel.

3.6.5 *Telescopic or Collapsible Cradle* — Telescopic or collapsible cradles are merely separate bogies carrying the keel blocks, interconnected by chains or drawbars. The outer bogie wheels are flanged and run on rails of heavy section, while the centre wheels on each side of the pawl rack may be flat rollers running on steel joists.

Any bogies can be moved to one side to allow clear access to the vessel's bottom. This type is probably the most economical in initial cost as the underwater track may be considerably shortened and considerable saving on costly underwater construction can be effected. The disadvantage of the collapsible cradle is the concentration of the load in a few points throughout the length, requiring heavy section of supporting beams, particularly on piled foundation. A further drawback is the damage caused by the binding of the wheel flanges against the rails. Owing to the short wheel base of each bogie the vessel may settle on the leading block at an angle which is not square to the bogie axle; so that on hauling up, the wheel flanges are not in line with the rails. The vessel setting on the carriages in this position renders the whole system rigid and high lateral stresses are imposed on the rails and beams. To prevent such happenings, the carriages may be fitted fore and aft of the wheels, with projecting plates bent under the bulb of the rails to serve as a guide and hold the carriage to the track.

3.6.6 *Cradle Supports*

3.6.6.1 The roller system, using wheel and bearing system has certain advantages, namely a small height of cradle structure and a low weight, together with simple lubrication. But there is a limit imposed by the maximum allowable axle bearing pressure, which should be taken into account when consideration is given to heavy local loads which may arise, for example, at the point of full sue in normal docking or when attempting to dock a vessel which has sustained a severe-damage below the water line.

3.6.6.2 The live roller system has certain advantages, principally in the reduction of friction and consequent reduction in the power required for haulage. Further the heavy load is distributed over the bodies of the rollers and is not sustained by the axle and bearings. On the other hand, there is the disadvantage that a considerable portion of the roller frame is permanently submerged and inaccessible for ready examination, maintenance and repair.

3.6.6.3 The combination of the two systems could also be adopted for slipways for heavier vessels, that is, live roller system on the central track and wheel and bearing, on the side tracks. Thus heavy central distributed load imposed by the vessels keel could be efficiently dealt with by central roller path, and the necessary bilge support by the wheel and bearing system. There would still exist of course the disadvantage of considerable part of the roller form of central track being permanently under water.

3.6.7 Where the slip is required to cater for vessels which house their engines and heavy haulage gear aft, determination of a precise loading layout for the cradle is not possible unless a study of numerous types and sizes of vessels is made. Again, vessel which is shorter than the cradle and is of rectangular or barge shape will impose heavy sue loads part of the way down the cradle. Accordingly, the first section of cradle will have to bear higher sue loads than the remaining sections of the cradle.

3.6.8 All cradles should preferably be provided with keel blocks and for bigger vessels with bilge blocks. Generally, the bilge blocks system should be designed for side supports to vessel loads due to winds acting on broadside of the vessel while hauling.

3.7 Haulage

3.7.1 The hauling gear in general consists of powerful winches worked by steam, diesel or electricity. For haulage wire ropes or endless chain system is used.

3.7.2 The slipways may be operated by an electric motor through two or three trains of spur reduction gears, clutches being provided to enable the main drum to be freed for the return of the empty cradle. A further

development is the use of electrically-driven variable speed gears, comprising a pump and hydraulic motor with oil as the media.

3.7.3 In some cases, direct acting hydraulic rams are used, connected to the cradle by means of a series of steel links, each link being of a length equal to the stroke of the ram. After each stroke, the cradle is arrested and one link is removed, the cross head of the ram being made fast to the next. Later development in this system has obviated the necessity of removal of links.

3.7.4 Cradles may be lowered by the backhaul system similar to the uphaul with the help of the winch by reversing the mechanism to control the speed of downhaul.

3.7.5 The pull on the hauling chain can be calculated from the following expression:

$$P = W (S + C)$$

where

P = pull on the hauling chain in tonnes;

W = weight of the vessel + the weight of the cradle + the weight of hauling chains and ropes in tonnes;

S = tan θ, where θ is the angle of slop of the slip; and

C = coefficient of friction which may be taken as 0·035 for wheels and 0·04 for rollers.

3.8 Other Repair Facilities

3.8.1 It would be desirable to provide sheds of sufficient height to clear mast of the vessel, over the repair-berths so that repair works may be carried out at all seasons with reasonable protection from the weather.

3.8.2 It is advantageous to provide suitable crane facilities for the work, either a mobile crane or a travelling crane on independent level track and foundation along one side of the slipway with sufficient jib length to plumb at least the middle of the vessel.

3.8.3 A suitable water jet arrangement to clear the silt, debris, etc, that may collect over the ways and floor, should be provided. In waters of high tidal range it may be expedient to provide flushing basin at the shore end of the slip. This is filled to high tide level and then at or near the time of low water, valves are opened and the water directed in a strong stream to clear the ways.

3.8.4 Adequate and well planned workshop facilities with plate bending, welding, smithy, carpantry and machine shops should be located as close to the slipway as possible.

3.9 The height of the top of the rails above high water mark is governed by the working headroom from the underside of the vessel's bottom to deck floor between the tracks; below high water mark the rails may be at beach level. The working headroom is usually 1·1 metre minimum.

3.10 Buffer stops should be provided at the bottom or sea end of the slip to prevent the cradle from running off the rails, and at the top end a single stop for the bridle bogie on the central rail to prevent over-winding. The buffer stops at the bottom end of the ways should be adequate to absorb the energy of empty cradle travelling at a speed down the inclination of the ways.

4. DESIGN

4.1 Length of Slipway

4.1.1 Slipways are generally designed to be not less than $2\frac{1}{2}$ times the length of the largest vessels to be accommodated. The length and draft of the vessel to be catered for, the slope of the slipway and height of the blocks above rail level are the influencing factors in determining the length of slipway. The following expression takes these factors into consideration:

$$L = 2l + s(d + h) + 6$$

where

L = length of slipway in metres,

l = length of vessel between perpendiculars in metres,

s = horizontal distance for unit rise of slip inclination,

d = draft of vessel at forecastle bulkhead in metres, and

h = height from rail level to top of blocks in metres.

4.1.1.1 The length L should be increased to account for an extension seawards for downhaul extension gear. If it is intended to slip the vessel at any other state of tide than the high water, this length should further be increased by the length falling within this tidal range.

4.1.1.2 In determining the overall length of the slipway, allowance should also be made for the clearance of about 60 cm over the draft of the vessel to allow for the contingency that may arise at times of slipping of damaged or waterlogged vessels.

4.1.2 In water of large tidal range, considerable economy in the construction of the underwater portion of the slipway may be effected by obviating the necessity of providing cofferdam for the construction, if slipping operation is restricted to high water or within a short range from high water.

4.2 Inclination of Slipway

4.2.1 The inclination of the slipway may vary between 1 in 12 to 1 in 30. It is found that the most economical and convenient slope is between 1 in 12 to 1 in 15. A steeper slope has the disadvantage of heavy haulage and a shore-end too high for convenient work. A lesser slope, whilst being less exacting on the haulage, leads to a long slip and long haulage wires, thus entailing heavy initial outlay and maintenance. In case of a very flat slope, the natural tendency of the cradle to go down under its own weight would be so reduced as to impose a severe load on the backhaul foundation.

4.2.2 To off-set the disadvantage, in case of steep-sloped slipway, of shore end of the vessel in dry position being much higher than the other, curved profiles to suit the natural back slope may be adopted in lieu of uniform inclination, but the radius of curvature should be constant throughout.

4.3 Vessel's Weight and Tonnage

4.3.1 A vessel's weight for dry docking is the unladen weight of the vessel including the weight of fuel, stores and water, etc, but excluding cargo. The displacement of the vessel in laden and unladen conditions is usually available in the ship's records. In absence of this information, the displacement weight may be determined by the following formula:

$$W = L \times B \times D \times C$$

where

W = displacement weight of vessel in tonnes;

L = length of the vessel between perpendiculars in metres;

B = breadth of the vessel at the waterline amidship in metres;

D = mean of the draft of the vessel fore and aft in metres; and

C = block coefficient, that is, the ratio between the volume of the wetted portion of the vessel and the volume of the enclosing block.

If the block coefficient, C, is unknown, the following table of approximate values for respective type of vessel in the light condition may be found useful.

Type of Vessel	*Block Coefficient, C*
Ocean cargo ship	0·56 to 0·65
Ocean tankers	0·60 to 0·70
Ocean tugs and trawlers	0·54 to 0·56
Passenger liner	0·55 to 0·60
Naval destroyers	0·52
Naval cruisers	0·57
Fishing vessels — small to big	0·40 to 0·60

4.4 Loads

4.4.1 Load distribution on the cradle and slipway due to the vessel varies with the type, size and shape of the vessels. However, determination of the distribution of load on the cradle is necessary for the design. The nearest approximation of load distribution may be done by drawing load distribution curves for several typical shapes and sizes of vessels that are likely to be hauled on the slipway on the basis of their volumetric displacement, because the distribution of weight of the vessel on its keel is proportional to the loss of buoyancy of the vessel. By knowing the layout diagram of the vessels for light draft condition, the volumetric displacements may be established as follows:

a) Divide the vessel into different segments;

b) Calculate the volume of each segment below the light draft water line including the overhanging portions, if any;

c) Plot the load diagrams for the supported length of keels on the cradle by multiplying the volumetric displacements with the specific gravity of sea water; and

d) Draw a line enveloping all the diagrams for different vessels, which becomes the load diagram for the cradle.

The above loads along with the self-weight of cradle are transferred to the slipway at the wheel points of the cradle.

4.4.2 *Sue Load*

4.4.2.1 A concentrated load called sue load is induced on the cradle and the tracks at inboard and outboard ends of the cradle while hauling and this load is to be calculated to determine whether the sue load or the distributed load mentioned in **4.4.1** is greater at any point.

4.4.2.2 As the cradle along with the vessel is hauled, the magnitude of the load increases from the point of first contact of the vessel with the cradle and becomes maximum just before the vessel is about to loose all its buoyancy. Sue load normally varies from 1/3 to 1/8 of the light displacement of the vessel depending upon the shape and size.

4.4.2.3 *Calculation of sue load* — The sue load is calculated as follows:

a) About the point of intersection of light draft water line with the keel line at the aft of the boat or boats, calculate the moment of volume of each of the segments below light draft water line and find the sum of all the moments and the volumetric displacements.

b) Find the distance of the centre of buoyancy by dividing the total moment obtained for the light draft condition by the sum of the total volumetric displacement for the same and from this distance subtract the distance between '0' and the first point of contact of the vessel with the cradle (×), which gives the distance to the centre of buoyancy from point ×.

c) Find the moment of the total volumetric displacement at light draft position and obtain the new moment about the point '×'.

d) Work out the volumetric displacements for the different portion of submerged segments for 3 to 4 positions of water lines below and inclusive of the light draft water line, imagining the vessel is hauled and drawing the waterline position on the vessel for the respective inclined positions of the vessels.

e) Tabulate for each different water line, the volumetric displacement of the position of submerged segments, and their moments, about the point '×'.

f) Draw a graph of the sum of the moments against the sum of the displacements for the different water lines obtained from (e).

g) Mark the moment determined as per (c) on the graph and get the corresponding displacement.

h) Subtract the displacement determined as per (g) from the total displacement of the vessel at light draft position which gives the sue load at the first point of contact.

4.4.3 The cradle should preferably be designed for the higher of the loads obtained by either sue load calculation or load distribution. The entire slipway except for the lowest 1/3 of the cradle length should also be designed for the higher of the two loads and the lowest and 1/3 cradle length for the weight of the cradle only so that the structure will be safe for all possible types and sizes of vessels, unexpected loads and different position of tides, etc.

4.5 *Foundations*

4.5.1 The form of slipway and the nature of the ground to a great extent determine the most suitable form of construction. Foundation should, if possible, be absolutely incompressible, but failing that, a very slight settlement is permitted, provided it is uniform throughout. Risk of uneven settlement should be avoided otherwise damage may be caused to the ship by broken cradles or rollers.

4.5.2 In soil with good bearing capacity, spread foundations or a form of mattress construction under the tracks connected by concrete floor may be used. A sheet pile cut-off wall should be provided at the water-end to protect spread or raft foundations against undermining by scour.

4.5.3 When the soil is of low bearing capacity, piled foundation with rail track supported on mild steel sections, spanning the pile bents may be used. The pile caps to which steel work is secured should be reinforced concrete construction.

4.5.4 The foundations shall be so designed as to take into account the probability that the whole weight of the vessel may have to be carried by the central track.

4.5.5 Where the slipways are required to handle bottom dump barges, which would impose heavy loads towards each side of the cradle over a considerable portion of its length, all three ways should be of robust construction. However, in such cases it may be economical to construct the slipways with two tracks only since the added cost of construction for strengthening the three ways would be more than offset by the economy of constructing only two ways, particularly in underwater section. Moreover, it would be easier to align two tracks accurately under water than three.

4.5.6 Heavy lateral forces will be induced across the slips by the cradles due to self alignment in any type of cradle and may be approximately calculated from the hauling load and the speed of haul. However, reduction in lateral forces may be effected with wheels of cradles having flanges alternately inside and outside.

5. CONSTRUCTION

5.1 As the lower end of a slipway is under water, a cofferdam is usually necessary for its construction in most cases, except when tidal range is large and vessels are proposed to be slipped at or near high water. The weight to be supported on the cradle over the underwater portion of the way diminishes as the ways get deeper and the load on the extension will probably be only that of the weight of the cradle. The foundation for the extension portion therefore need be much lighter in construction.

5.2 It is essential that alignment and levelling of rail tracks requiring greater accuracy should be done in the dry. Accurate work under water needs more time, skill and experience and for a permanent slipway, a cofferdam would be advantageous; in any case, it is just as cheap and as quick as working under water.

5.3 The construction of slipways with pile foundation is advantageous and economical under suitable site conditions. Tidal and under water excavation for continuous footings is very troublesome at some sites, especially where soft mud overlays a good substratum of gravel or sand and after completion sometimes even during construction, siltation and scouring of continuous walls present another problem; in such cases, piled slipways are recommended. In actual construction, driving the piles to an accurate line and level is difficult and as a result, considerable delays may occur.

5.4 The following constructional tolerances are allowed:

a) Along the line of slip: $\pm$ 10 mm, with a maximum rate of change of 10 mm in 5 metres or 20 mm in 15 metres.

b) Across the slip: 10 mm in levels.